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SOLAR SYSTEM DUST DATA Final  
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**FINAL TECHNICAL REPORT**

NASA Grant NAG 5-1261

*"Analysis of IRAS Solar System Dust data."*

6/01/1989 — 12/31/1991

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This research, initially approved for the three year period 6/1989 – 5/1992, was carried out at Cornell University and at the University of Florida under this grant number for the first two years. For the recently-completed third year, the grant was renewed at Univ. Florida under Dr. Dermott as P.I., with a sub-contract to Cornell. This report covers work done during the first two years under NAG 5-1261.

**Scientific goals**

The major tasks outlined in the original proposal were to analyse the data in the IRAS Zodiacal History File in order (1) to show that the prominent solar system dust bands are associated with Hirayama asteroid families and thus that collisions between asteroids account for a significant fraction of the particles in the zodiacal cloud, (2) to show that there is evidence in the IRAS dust data for the transport of particles from asteroid belt to the Earth by Poynting-Robertson light drag and thus account for the fact that asteroidal particles are collected in the Earth's stratosphere, and (3) to construct a model of the background zodiacal cloud that satisfies the proper dynamical constraints.

The work that has been completed in the past year that has enabled us to reach the above goals has included:

**Summary of work completed**

In April 1989 the Infrared Processing and Analysis Center (IPAC) at Caltech delivered, at our request, a high resolution version of the Zodiacal History File (ZHF) containing the complete IRAS sky survey data at a resolution of  $\sim 2$  arcminutes ( $1/32$  degree) in a direction perpendicular to the ecliptic plane. This data set, which has proved vastly more suitable for studies of the dust bands than the original  $1/2$  degree ZHF, has formed the basis of our investigation. During the following two years, we analyzed and extracted band location and peak brightness measurements from approximately 1000 individual IRAS scans, using essentially the entire dataset with the exception of regions strongly contaminated by Galactic emission. The attached Figs. 1 and 2 show a typical set of scans, processed via a Fourier filter to remove the much stronger zodiacal background and Galactic signals, and the resulting polynomial fits to the 25 micron scan. The latter provide objective estimates of band widths, peak locations and peak fluxes.

Utilizing the original IRAS survey strategy, whereby the sky was divided into 'lunes' 30 degree in longitude wide, we then systematically fitted the data acquired for each of the 12 lunes to determine the mean latitudes of the Central and 10-degree bands (North and South), corrected to a uniform elongation angle of 90 degrees; and also the local distance

to the 10 degree bands in each lune. The latter utilized a form of parallax measurement previously applied to lower resolution measurements around most of the sky (Dermott *etal.* 1989). The variation in mean latitude around the sky provides a sensitive determination of the orientation of the symmetry plane of the dust bands, and thus, via the theory of secular perturbations, an independent estimate of their distance (Dermott *etal.* 1985, 1986).

Our results, while confirming the location of the dust bands within the inner asteroid belt (Low *etal.* 1984; Dermott *etal.* 1984), show conclusively that the material seen by IRAS is now spread over wide range of distances from the sun, from a maximum near 3 astronomical units (AU), at the presumed source(s) of the dust in asteroidal collisions, in to the orbit of the Earth at 1 AU, and perhaps even closer to the sun. This conclusion is derived from the second major thrust of our work, which was to formulate an accurate numerical model of the dust distribution in 3 dimensions, taking into account both planetary perturbations and inward evolution due to Poynting-Robertson drag (Gomes *etal.* 1990). This model, developed under this Grant and its predecessor over a period of several years, is now capable of accounting not only for the observed peak latitudes and widths of the dust bands, but also for their detailed morphology. Examples are shown in Fig. 3. The agreement between model and observations over the full range of geometries sampled by the IRAS data give us considerable confidence in our conclusions.

More recent work has suggested that, while the Hirayama families we originally proposed as sources of the dust in the bands undoubtedly play a major role, there may also be contributions from two or three smaller, more recently recognised asteroid families at slightly different mean inclinations.

The analysis of the full IRAS dataset has now been completed, and modelling and analysis of the resulting band data was largely completed in 1991/1992, in the second and third years of this work. Summaries of the main results have been presented in several conference proceedings (Dermott *etal.* 1988, 1989, 1990, 1992), in a chapter on solar system dust bands in the book 'Asteroids II' co-authored with M. Sykes, and at numerous presentations at scientific meetings (see list of publications below). The full set of results, covering the central bands, the 10-degree bands, and the zodiacal background, are currently in preparation for submission to *Icarus* as three companion papers. A separate paper describing the numerical dust model, and the underlying dynamical calculations of dust evolution, is also planned. Phases of this work will form major sections of the Ph.D. theses of two graduate students at the University of Florida.

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  - 6) Dermott, S.F., and P. Nicholson, IRAS Dust Bands and the Origin of the Zodiacal Cloud. *Highlights of Astronomy* 8, 259-266 (1989).
  - 7) Gomes, R.S. and S.F. Dermott, Forced Orbital Elements of Zodiacal Cloud Particles. *Bulletin of the American Astronomical Society*, 22, 1123 (1990).

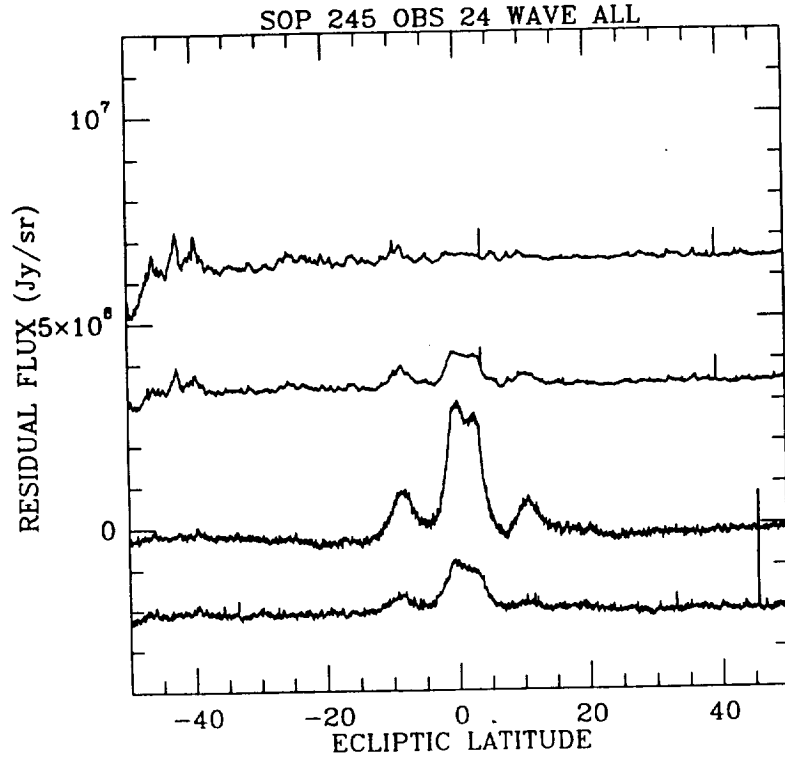
### **Publications under this Grant**

#### **Papers**

- 1) Dermott, S.F. and P.D. Nicholson. (1989), IRAS Dust Bands and the Origin of the Zodiacal Cloud. *Highlights of Astronomy* 8, 259-266.
- 2) Sykes, M.V. R.J. Greemberg, S.F. Dermott, P.D. Nicholson, J.A. Burns, and T.N. Gautier, III. (1989), Dust Bands in the Asteroids Belt. In *Asteroids II* (eds. R. Binzel, T. Gehrels, M. Matthews), University of Arizona Press, pp. 336-367.
- 3) S.F. Dermott, P. Nicholson, R.S. Gomes, and R. Malhotra. Modelling the IRAS Solar System Dust Bands. *Adv. Space Res.* 10, (3)171-(3)180 (1990).
- 4) Dermott, S.F., R.S. Gomes, D.D. Durda, B.A.S. Gustafson, S. Jayaraman and Y.-L. Xu, (1992), Dynamics of the Zodiacal Cloud. In *Chaos, Resonance and Collective Dynamical Phenomena in the Solar System*, (eds. S. Ferraz-Mello), pp. 333-347.

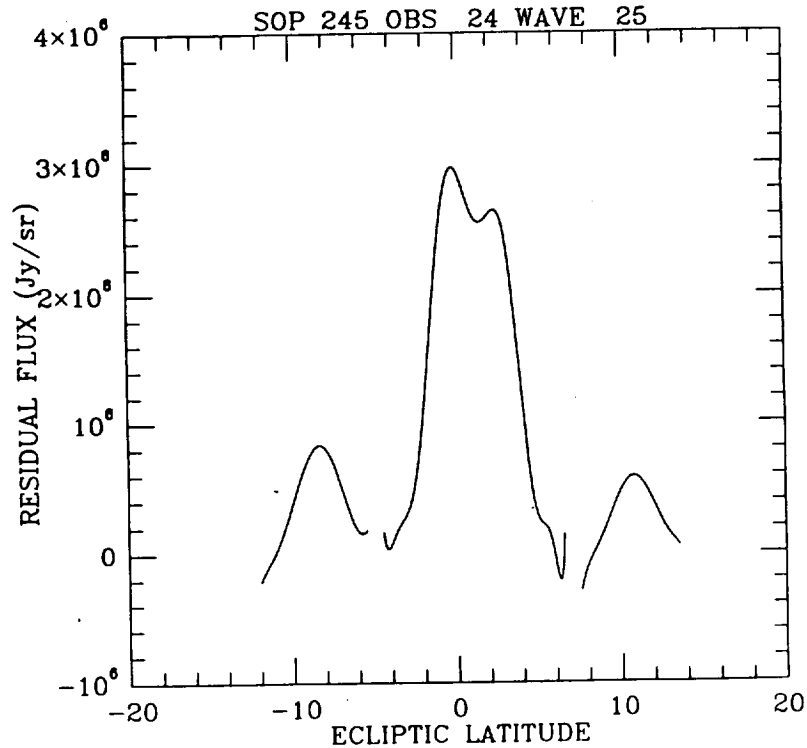
#### **Abstracts**

- 1) Gustafson, B., S.F. Dermott, R.S. Gomes. Distribution and Thermal Properties of Dust Particles in the Zodiacal Cloud. *Bulletin of the American Astronomical Society*, 22, 1123, 1990.
- 2) Jayaraman, S., S.F. Dermott, R.S. Gomes, B. Gustafson, C. Simpson, Y.-L. Xu, P.D. Nicholson. IRAS Observations of the Ten-Degree Solar System Dust Bands. *Bulletin of the American Astronomical Society*, 22, 1123, 1990.
- 3) Gomes, R.S., S.F. Dermott, Forced Orbital Elements of Zodiacal Cloud Particles. *Bulletin of the American Astronomical Society*, 22, 1123, 1990.
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- 5) Xu, Y.-L., S.F. Dermott, B. Gustafson, S. Jayaraman, D.D. Durda. Modeling of the Zodiacal Dust Cloud, *Bulletin of the American Astronomical Society*, 23, 1149, 1992.
- 6) Durda, D., S.F. Dermott. Modelling of Asteroidal Dust Production Rates, *Bulletin of the American Astronomical Society*, 23, 1150, 1992.



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Fig. 1. A set of scans from the new high-resolution ( $2''$ ) ZHF, Fourier-filtered to remove the broad zodiacal background signals. From top to bottom, the wavelengths are 100, 60, 25 and 12  $\mu\text{m}$ ; the dust bands are most prominent at 25 and 60  $\mu\text{m}$ , and essentially absent at 100  $\mu\text{m}$ . Spikes represent bright point sources crossed by the  $0.5''$  wide scan. The zero levels of the 12, 60, and 100  $\mu\text{m}$  scans have been offset for clarity. Note the diffuse appearance of the bands at  $\pm 10^\circ$ , in comparison with the sharp-edged central band complex.



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Fig. 2. Polynomials of 7<sup>th</sup> order fitted separately to the three principal 25  $\mu\text{m}$  bands in Fig. 1. Such fitted curves accurately reproduce the shapes of the observed dust bands, as derived from our filtering procedure, and provide the basic data on peak latitudes and band widths for geometric modelling.

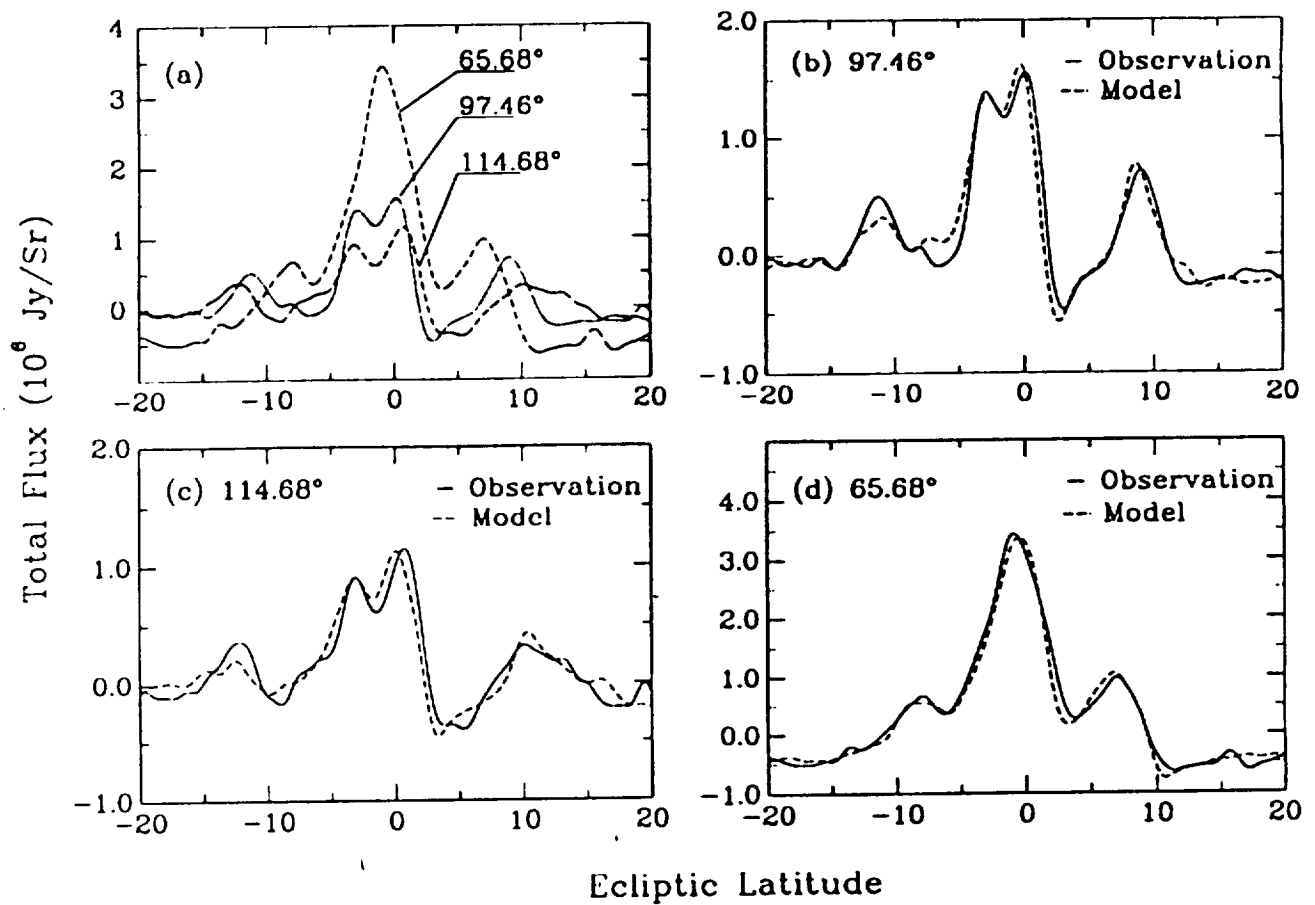


Fig. 3. IRAS observations of the solar system dust bands at solar elongation angles of  $65.68^\circ$ ,  $97.46^\circ$ , and  $114.68^\circ$ , compared with numerical model profiles for dust originating in five prominent Hirayama families but distributed over the radial range 0.5 to 3.0 AU due to Poynting-Robertson drag.